2.22 DETECTION THRESHOLD

The detection threshold of a radar is the minimum target-signal power for which the radar can detect a target, with a given probability of success, in the presence of the radar thermal noise and/or some external influence. Since the factors influencing target detection are generally noise-like (randomly occurring), the criterion for detection is usually described by some form of probability distribution with associated probabilities of detection (P_d) and false alarm (P_{fa}). Signal integration and signature fluctuations (described in Sections 2.25 and 2.4, respectively) are closely related to this functional element.

Thresholding can be modeled at levels ranging from a simple envelope detection using a signal-to-interference ratio (S/I) test to a comprehensive representation of a cell averaging constant false alarm rate (CFAR) system. In the simple S/I methodology, target detection occurs provided that S/I exceeds a pre-specified value (the threshold). In the next step up in complexity, the P_d is calculated. In this case, detection can be based either on this probability exceeding a certain value, or on a random draw.

The most complex modeling of threshold, not appropriate for all radars, simulates a cell averaging CFAR process that adjusts the detection threshold as a function of the environment while maintaining a constant false alarm rate. This process establishes range bins and doppler filters that are monitored for the presence of a target at a certain azimuth and elevation. Cell averaging CFAR ensures that the false alarm rate is not excessive, even though the radar is operating in a cluttered background or in the presence of some types of electronic countermeasures. The threshold for an individual CFAR cell is adjusted by sampling the energy in a selected number of cells adjacent to the target cell. The energy is averaged and multiplied by a factor which is a function of the P_{fa} and the number of cells monitored.

In RADGUNS, either the S/I or P_d is compared with a user-selectable value to determine detection; CFAR is not modeled. The purpose of the Detection Threshold Functional Element in RADGUNS is to establish a target detection status.

2.22.1 Functional Element Design Requirements

This section contains the design requirements to implement the threshold simulation in RADGUNS.

a. The user will have the option of determining target detection status either by use of S/I comparison with a user-defined threshold for detection, or by use of P_d comparison with a user-defined P_d requirement for detection.

b. The bias level will be the minimum voltage level at the output of the radar receiver that is required for signal detection. This voltage level can be exceeded by a signal due to noise sources or a signal from a target return.

c. The Detection Threshold Functional Element will utilize the P_d model developed at the Johns Hopkins University (JHU) Applied Physics Laboratory to calculate the bias level.

d. The P_d calculated by the JHU model will be compared with a user-defined requirement for detection if the P_d model is chosen by the user.

2.22.2 Functional Element Design Approach

This section describes the design approach used to fulfill the FE design requirements. The approach is subdivided by design element, which is an algorithm that represents a specific component of the FE design. The target detection decision in RADGUNS depends on the user's choice of data type used for threshold comparison purposes. One type is S/I. The other data type is P_d which is an input to this FE from FE 4, Signature Fluctuations. The method for determining the appropriate threshold value is described in Design Element 22-1. Either the P_d or S/I is used for a detection decision as described in Design Element 22-2. One input to P_d calculations (in FE 4) is the bias level, which is part of the Detection Threshold FE. An approximation technique is used to identify the bias level; this technique is explained in Design Element 22-3. The bias level depends on the false alarm number, which is described in Design Element 22-4.

Design Element 22-1: Identifying a Threshold Value

The user defines a P_d “threshold” if the use of S/I for thresholding is not preferred; if S/I is preferred, two user-defined S/I values are available for threshold considerations. One S/I value is used in a clutter environment, which exists when ground clutter is greater than or equal to one-tenth of the target return. The other S/I is used in a non-cluttered environment, when the clutter is less than one-tenth of the target return.

[NOTE TO DEVELOPER: No reference was found to support checking that clutter is less than one-tenth of the target return. Is the one-tenth criteria valid?]

Design Element 22-2: Detection Decision

A comparison of either S/I or P_d with a user-defined threshold is performed in this design element. Given a value, *X* (either a P_d or a S/I), a yes or no decision, D, is made about target detection. This is based on the threshold requirement, *T*, for detection. The algorithm for this design element is described as follows:

$$\begin{aligned} &\text{If} \quad X > T, \ \text{then D = Yes} \\ &\text{If} \quad X \le T, \ \text{then D = No} \end{aligned} \qquad [2.22\text{-}1]$$

<u>Bias Level and False Alarm Design Elements</u>. The P_d depends on the bias level of the system. The bias level is the minimum voltage level at the output of the radar receiver that is required for signal detection. Note that a signal above the bias level could be produced by noise voltage; this occurrence is a false indication of a target (false alarm).

In RADGUNS, the bias level is calculated using the methods of References 14 and 15. According to Reference 14, equation 2-14, the probability density function (f¢) for noise alone is given by

$$f'(Y) = \frac{Y^{N-1} e^{-Y}}{(N-1)!} \qquad [2.22\text{-}2]$$

where N = number of pulses integrated
Y = instantaneous noise amplitude at the output of a square-law detector normalized to the root-mean-squared (RMS) video noise voltage.

The P_{fa} is determined by integrating f¢ over appropriate limits (Reference 14, Equation 2-15).

$$P_{fa} = \int_{Y_b}^{\infty} f'(Y)dY \qquad [2.22\text{-}3]$$

where Y_b = bias level

The P_{fa} can be related to the Fehlner's false alarm number, $n¢$, by use of Marcum's definition of false alarm time. This definition states that the probability is 50% [$P_{(fa=0)}$ = .5] that noise will not exceed the bias level in any given false alarm time (Reference 14, page 22). $n¢$ is the number of independent opportunities for a false alarm in the false alarm time; the false alarm time is the time period during which the probability (P_0) that a false alarm will not occur. As discussed above and for purposes of standardization, P_0 is set to 0.5 (Reference 15, page 5).

$$P_{fa} = 1 - P_0^{1/n'} \qquad [2.22\text{-}4]$$

where P_0 = probability of no false alarm in the false alarm time (= 0.5)
$n¢$ = false alarm number

Combining Equations [2.22-3] and [2.22-4] yields

$$P_0^{1/n'} = 1 - \int_{Y_b}^{\infty} f'(Y)dY \qquad [2.22\text{-}5]$$

by the definition of a probability density function

$$\int_{0}^{\infty} f'(Y)dY = 1 \qquad [2.22\text{-}6]$$

Combining Equations [2.22-5] and [2.22-6] with [2.22-2] produces

$$P_0^{1/n'} = \int \frac{Y^{N-1}e^{-Y}}{(N-1)!}dY \qquad [2.22\text{-}7]$$

Since P_0 = 0.5 and $n¢$ is set to a constant value, Equation [2.22-7] may be solved for Y_b.

$$\begin{aligned} &\text{Let} \quad f(Y) = \int \frac{u^{N-1} e^{-u}}{(N-1)!} du \\ &\text{so,} \quad f(Y_b) = P_0^{1/n'} \end{aligned} \qquad [2.22\text{-}8]$$

To solve for Y_b, first note that repeated integration by parts yields

$$f(Y) = 1 - \sum_{k=0}^{N-1} \frac{e^{-Y} Y^k}{k!} \qquad [2.22\text{-}9]$$

Solving this series for Y is not trivial; therefore, Heun's method is used. This method involves selecting a value, Y_0, as an initial approximation to Y_b, and then uses the concept of the integral as the area under the curve to make successively better approximations to Y_b. This method is described in the following design element descriptions.

Design Element 22-3: Bias Level Approximation Technique

An initial estimate of the bias level, Y_0, must first be identified as a basis for successive approximations. The estimate depends on the number of pulses integrated, N, as follows: (Reference 14, equations A-116 and A-117):

$$Y_0 = N\left[1 + 2.2\left(\frac{\log_{10} n'}{N^{\left(2/3 + 0.015 \log_{10} n'\right)}}\right)\right] \quad \text{if } N \le 12 \qquad [2.22\text{-}10]$$

$$Y_0 = N\left[1 + 1.3\left(\frac{\log_{10} n'}{N^{\left(1/2 + 0.011 \log_{10} n'\right)}}\right)\right] \quad \text{if } N > 12 \qquad [2.22\text{-}11]$$

The bias level, Y_b, is identified by finding approximate values of Y_b, (Y_0, Y_1, Y_2, …,) and values $f_j = f(Y_j)$. Y_0 was defined above, and by Equation [2.22-9], f_0 can be written as follows:

$$f_0 = f(Y_0) = 1 - \sum_{j=0}^{N-1} e^{-Y_0} \frac{Y_0^j}{j!} \qquad [2.22\text{-}12]$$

or

$$f_0 = 1 - \sum_{j=0}^{N-1} e^{-Y_0 + j\, ln(Y_0) - \sum_{i=2}^{j} ln(i)} \qquad [2.22\text{-}13]$$

f_0 is compared to $f(Y_b)$ = to determine the sign of the step size, h, for successive approximations to Y_b. This determination is based on Reference 15, page 30, and the step size used in RADGUNS is as follows:

$$h = \begin{cases} 0.1 & \text{if } f(Y_0) \le f(Y_b) \\ -0.1 & \text{if } f(Y_0) > f(Y_b) \end{cases} \qquad [2.22\text{-}14]$$

Then, for j = 0, 1, 2, …

$$Y_{j+1} = Y_j + h \qquad [2.22\text{-}15]$$

and

$$\begin{aligned} f_{j+1} &= f\left(Y_{j+1}\right) \\ &= f_j + \frac{h}{2}\left[f'\left(Y_j\right) + f'\left(Y_{j-1}\right)\right] \end{aligned} \qquad [2.22\text{-}16]$$

This approximation follows from the concept that $f_j = f(Y_j)$ is approximately equal to the area under the curve $w = f'(Y)$ from $Y = 0$ to $Y = Y_j$. Thus, f_{j+1} can be approximated by this area (f_j) plus the trapezoidal approximation to the area under the curve from Y_j to Y_{j+h}. Use of this methodology is based on Reference 14, equation A-118. Equation [2.22-16] is evaluated using a modified form of Equation [2.22-2].

$$f'(Y) = \frac{Y^{N-1}e^{-Y}}{(N-1)!} = e^{-Y} e^{\ln\left(\frac{Y^{N-1}}{(N-1)!}\right)} \qquad [2.22\text{-}17]$$

or

$$f'\left(Y_j\right) = e^{-Y_j + (N-1)\ln\left(Y_j\right) - \sum_{i=2}^{N-1} \ln(i)} \qquad [2.22\text{-}18]$$

Approximations are terminated when one of the following conditions is satisfied:

$$\begin{aligned} f_{j+1} &\ge f\left(Y_b\right) \quad \text{if} \quad f_0 \le f\left(Y_b\right) \\ f_{j+1} &< f\left(Y_b\right) \quad \text{if} \quad f_0 > f\left(Y_b\right) \end{aligned} \qquad [2.22\text{-}19]$$

This is implemented in RADGUNS by checking the following inequality:

$$\begin{aligned} f_{j+1} - (0.5)^{1/n'} &\ge 0 \quad \text{if} \quad h \ge 0 \\ f_{j+1} - (0.5)^{1/n'} &< 0 \quad \text{if} \quad h < 0 \end{aligned} \qquad [2.22\text{-}20]$$

The final value of bias, Y_b, is identified by interpolation. The form of the interpolation equation depends on whether the initial bias estimate, Y_0, produced a value of f greater than or less than. Thus, the interpolation depends on the sign of the step size h as follows:

$$Y_b = f\left(Y_{j+1}\right) - h\,\frac{f\left(Y_b\right) - f\left(Y_{j+1}\right)}{f\left(Y_j\right) - f\left(Y_{j+1}\right)} \quad \text{if} \quad h = -0.1$$

$$Y_b = f\left(Y_j\right) + h\,\frac{f\left(Y_b\right) - f\left(Y_j\right)}{f\left(Y_{j+1}\right) - f\left(Y_j\right)} \quad \text{if} \quad h = +0.1 \qquad [2.22\text{-}21]$$

where $f(Y_b) = P_0^{1/n'} = 0.5^{1/n'}$

Design Element 22-4: Design Element 22-4: False Alarm Number

Bias level calculations depend on the false alarm number. As mentioned in Design Element 22-2, the false alarm number, *n¢*, is the number of independent opportunities for a false alarm in the false alarm time, and the false alarm time is the time period during which the probability (P_0) that a false alarm will not occur (Reference 15, p. 5). The P_{fa} is system specific. Knowledge of P_{fa} allows *n*¢ to be derived from equation 2 of Reference 1:

$$P_0 = \left(1 - P_{fa}\right)^{n'} \qquad [2.22\text{-}22]$$

where P_0 = the probability of <u>no</u> false alarm during the false alarm time

As mentioned earlier, P_0 is set equal to 0.5 for purposes of standardization. Taking the natural logarithm of both sides of Equation [2.22-22] yields

$$ln\left(P_0\right) = ln(0.5) = ln\left[\left(1 - P_{fa}\right)^{n'}\right] = n'\; ln\left(1 - P_{fa}\right) \qquad [2.22\text{-}23]$$

This equation reduces to the final form for *n¢*:

$$n' = \frac{ln(0.5)}{ln\left(1 - P_{fa}\right)} \qquad [2.22\text{-}24]$$

2.22.3 Functional Element Software Design

This section contains the software design necessary to implement the functional element requirements and design approach described above. The first portion contains the subroutine hierarchy and descriptions. Logical flow diagrams and their descriptions are then presented. The final portion contains lists and descriptions of the input and output variables.

Detection Threshold Subroutine Design

RADGUNS uses Subroutine PDET to define the P_{fa}, and to calculate the number of pulses integrated. These two variables are passed to subroutine PRBDET, which performs the calculation of bias level used in the P_d model. PDET is called by different subroutines, depending on the radar search mode chosen by the user. The perfect cueing mode (Subroutine PERCUE) does not represent a real-world system; it maintains the antenna boresight pointing directly at the target. PERCUE is used when a radar search pattern is not known, or when target detection is not in question. A circular scan mode or sector search mode (Subroutine SRCH1) searches the sky until a target can be spotted on a PPI scope by an operator. Another circular scan mode (Subroutine SRCH2) also searches the sky until a target can be spotted on a scope. SRCH2 is included for completeness; it is not called for the specific system under study. The RADGUNS program main routine is called AAASIM. Figure 2.22-1 shows the call hierarchy associated with the Detection Threshold Functional Element. Shaded blocks in the call tree denote modules that directly implement the FE. Table 2.22-1 contains a brief description of each of these subroutines.

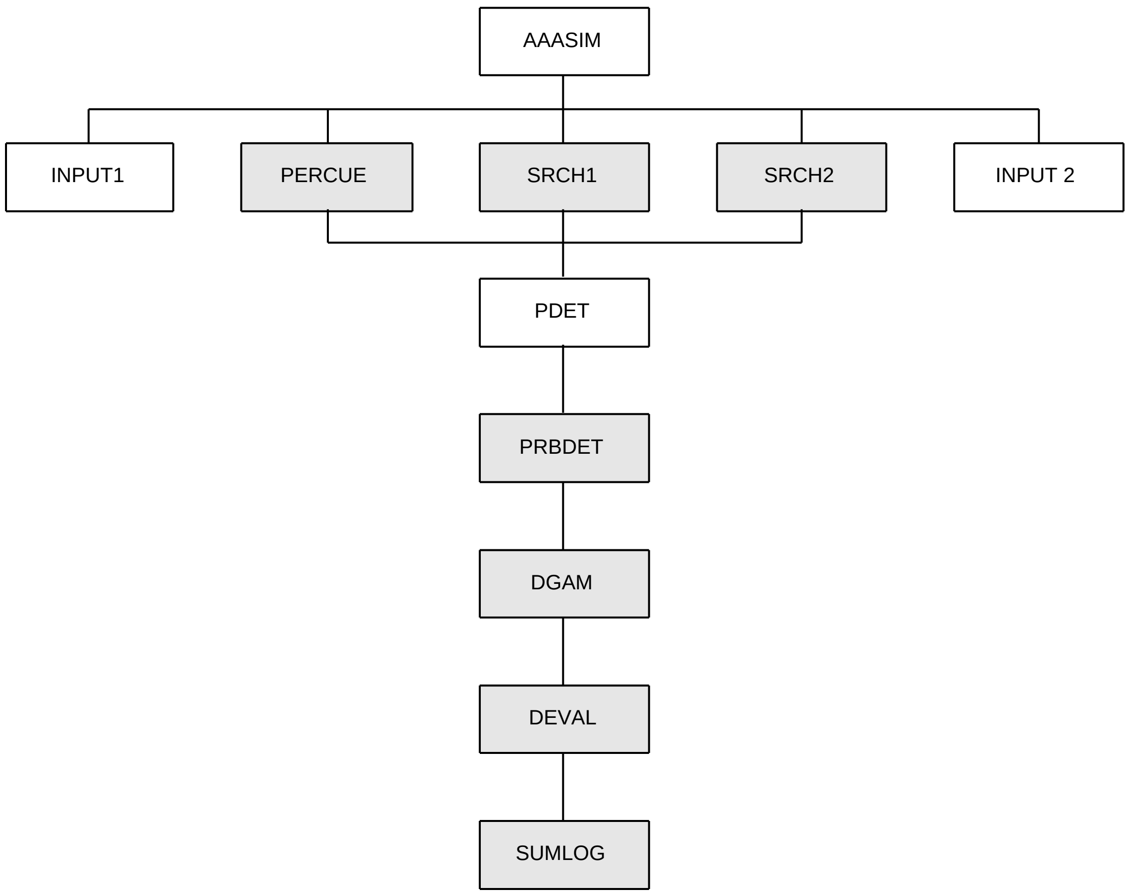

FIGURE 2.22-1. Call Hierarchy for Detection Threshold.

TABLE 2.22-1. Subroutine Descriptions.

Name	Description
INPUT1	Reads input parameters 1-8 from the input parameters file
INPUT2	Reads input parameters 9-27 from the input parameters file
AAASIM	Main routine to simulate AAA system
PERCUE	Search for target with antenna cued to target position
SRCH1	Search for target in sector scan or circular scan mode
SRCH2	Search for target in circular scan mode

TABLE 2.22-1. Subroutine Descriptions. (Contd.)

Name	Description
PDET	Calculates number of pulses integrated, defines Pfa
PRBDET	Calculates bias, and implements Pd model
DGAM	Main routine for calculation of incomplete gamma function
DEVAL	Calculates primary (maximum) term for series solution of incomplete gamma function
SUMLOG	Called by DEVAL to sum natural logarithms of integers
Note: Modules implementing the threshold functional element are identified in bold letters.	

Logical Flow Diagram for Detection Threshold. For the P_d model, the Detection Threshold FE is implemented primarily by subroutine PRBDET, where bias level calculations are performed. The functional flow diagram of calculations is included with the Bias Level Algorithm descriptions.

The bias is used in FE 4, target Signature Fluctuations, as input to the P_d model. The P_d is an output from that FE, which in turn is utilized by this FE for a detection decision.

The detection decision is a simpler process if the user selects the threshold detection model.

The detection decision is implemented by one of two subroutines for the subject system, depending on the search mode chosen by the user. If perfect cueing mode is chosen, Subroutine PERCUE performs the detection decision. If sector or circular search mode is selected, Subroutine SRCH1 investigates the detection status (SRCH2 operates circular mode also, but not for the subject system). These modes and the detection decision process are discussed under the Detection Decision Implementation heading.

The flow charts contain input, output, and internal variables that subsequently will be discussed. Variable names are enclosed in parentheses. The blocks are numbered for ease of reference in the diagram explanations.

Bias Level Algorithm. Figure 2.22-2 presents the flow diagram of calculations used to determine the bias level. Explanation of the flow diagram is presented after the figure.

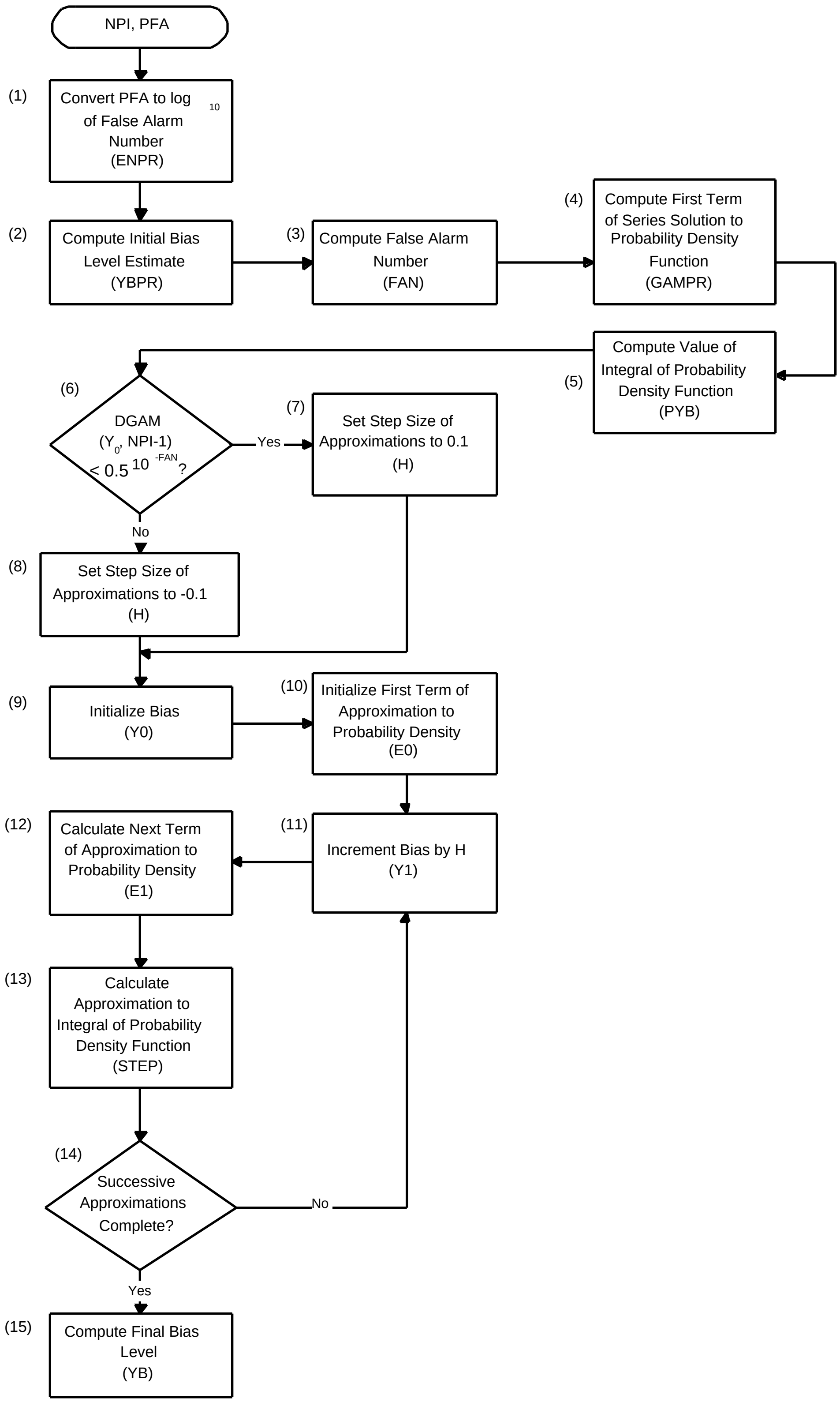

FIGURE 2.22-2. Bias Calculation Flow Chart.

Three modules are utilized (in bias calculations) which are explained in the target Signature Fluctuations FE. Although two of the three modules, DGAM and DEVAL, have different names than those of the fluctuations FE (GAM and EVAL), the functionality is exactly the same. Apparently, DGAM and DEVAL formerly were double-precision counterparts to the single-precision functions GAM and EVAL. However, all four functions currently are double-precision. In the Detection Threshold FE, DGAM calls DEVAL, which then calls SUMLOG. This trio of modules implements the solution to the incomplete gamma function; Section 2.4 explains the theory and RADGUNS implementation of that function.

[NOTE TO DEVELOPER: Why are modules duplicated (DGAM and GAM, DEVAL and EVAL) in the Pd model implementation?]

The number of pulses integrated (variable NPI) and the base ten logarithm of the false alarm number (variable FAN) are inputs to the algorithm for bias calculation.

<u>Blocks 1-2</u>. The base ten logarithm of the false alarm number (Equation [2.22-24]) is computed and stored in variable ENPR for use in Block 2. The initial estimate of bias (variable YBPR) is set depending on the value of NPI. If NPI [2.22-10] is used to set the initial bias estimate; if NPI > 12, Equation [2.22-11] is used.

<u>Block 3</u>. Subsequent calculations require the false alarm number which is 10ENPR.

<u>Block 4</u>. The design approach discussion before Design Element 22-3 revealed that to solve for the bias, the probability density function for noise is utilized. The series solution defined by Equation [2.22-9] is solved for the bias level. However, the first term of the series solution, f_0, is computed by substituting the initial bias estimate (YBPR) into the equation for the first term. This term is defined by Equation [2.22-13], and is stored in variable GAMPR.

<u>Block 5</u>. The value of the portion of the integral of the probability density defined by Equation [2.22-8] (in the range $Y = 0$ to $Y = Y_b$) is set to the value of $0.5^{1/n'}$ in variable PYB.

<u>Blocks 6-8</u>. If the first term of the series solution (GAMPR) is less than the value of the probability density function (PYB), execution transfers to Block 7, where the step size for approximations is set to +0.1 in variable *H*. Otherwise, the step size is set to –0.1 in Block 8. These three blocks implement Equation [2.22-14].

<u>Blocks 9 and 10</u>. The initial bias estimate from Block 2 is re-initialized as variable Y0. The first term of the approximation to the probability density function ($f'(Y)$) is calculated as defined by Equation [2.22-18], and is stored in variable E0.

A recursive algorithm is used to calculate successive approximations to the integral of the probability density function (using Heun's method). This is accomplished in Blocks 11-14.

<u>Blocks 11 and 12</u>. The bias level is incremented by H, and stored in variable Y1. Equation [2.22-18] again is used to calculate the next term of using the incremented bias value of Y1; the next term is stored in variable E1.

Block 13. The approximation, f_{j+1}, to the integral of the probability density is computed using Equation [2.22-16], and is stored in variable STEP. The first approximation to the integral, f_0, is GAMPR calculated in Block 4.

Block 14. The condition for completion of successive approximations is evaluated. Equation [2.22-20] is used to perform the evaluation. If further approximations are necessary, execution loops back to Block 11, where the bias is incremented, followed by calculation of the next approximation. If the approximations are completed, execution continues to Block 15.

Block 15. The integral approximation is completed by determining the final bias value, Y_b, by interpolation. Y_b is calculated using Equation [2.22-21], and is stored in variable YB.

Detection Decision Implementation. Figure 2.22-3 presents the flow diagram for the detection decision process for both the threshold detection model and the P_d model. This section applies to the three available search modes of perfect cueing, sector search, circular search; these modes are simulated for the applicable system by Subroutines PERCUE and SRCH1.

Variable names are capitalized and enclosed in parentheses in the flow chart explanation that follows. Several variables are inputs to the detection decision portion of the FE. These are the initial target status of “undetected” (RSTAT), detection model (DETTYP), antenna search pattern (SCHPAT), “threshold” for a P_d or a S/I threshold in a non-cluttered environment (THRESH(1)), and S/I threshold in a cluttered environment (THRESH(2), specified if the threshold detection model is chosen).

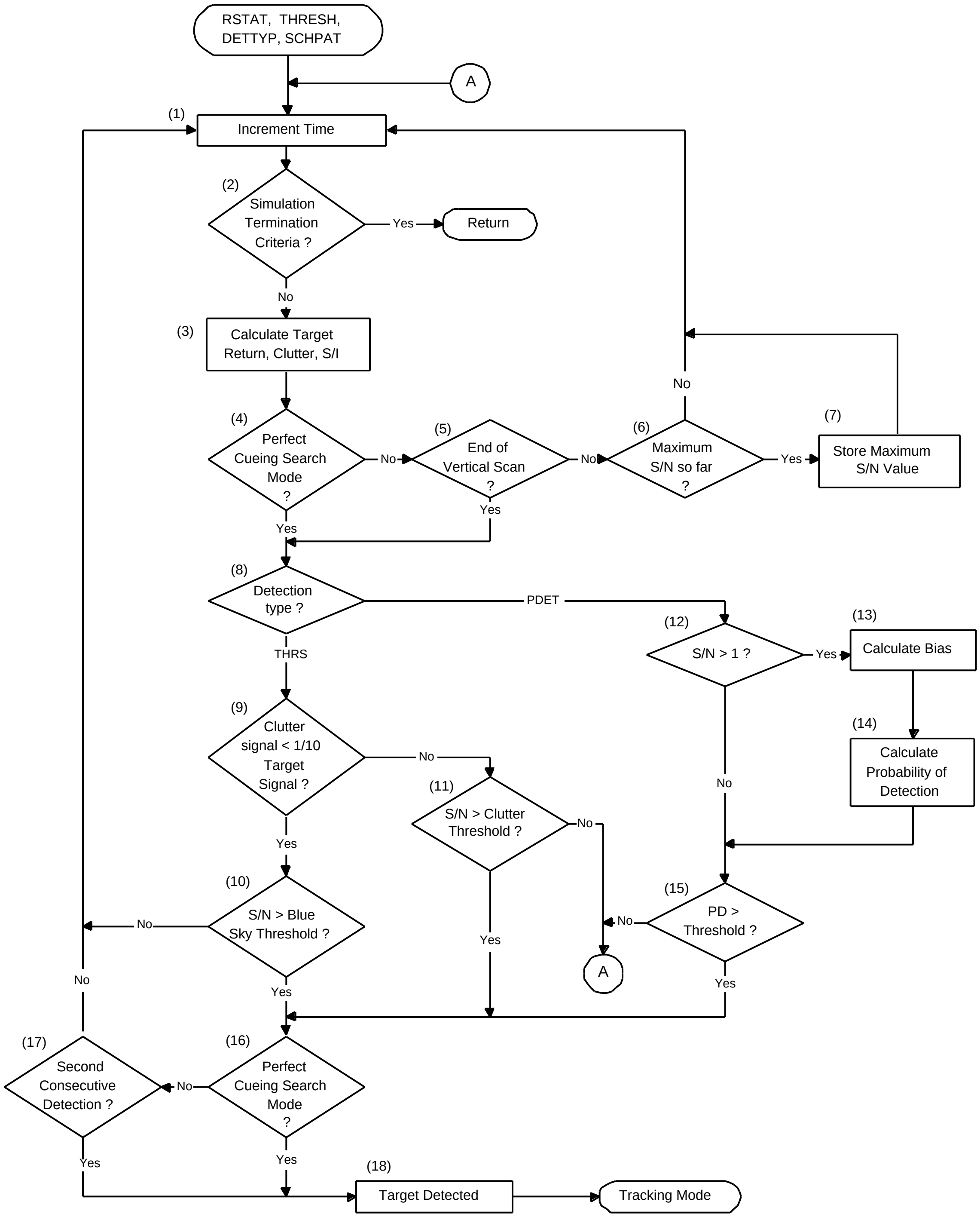

FIGURE 2.22-3. Flow Chart for Subroutines PERCUE and SRCH1.

Block 1. The simulation time is incremented (T).

Block 2. Many variables are calculated that are not part of the FE. These variables are checked to determine if a condition exists that could terminate the simulation. An example of such a condition is a target out of gun range and receding from the radar. Termination is denoted by the RETURN to the program main routine which ends the run; otherwise, Block 3 tasks are performed.

Block 3. The target return power (TS), ground clutter power (CL), and signal-to-interference ratio (SIRAT) are calculated, but are not part of the FE. Nonetheless, these three variables are utilized in the detection decision process.

Blocks 4-7. The S/I for a single pulse is used for threshold comparison purposes while a perfect cueing search pattern is utilized. However, when a sector or circular search pattern is used, all pulses in a vertical scan are evaluated to determine the maximum S/I; the maximum value is used for the final threshold comparison. If a vertical scan is not completed (Block 5), the S/I of the current pulse is compared with the maximum S/I (SIRATM) so far for the scan (Block 6). If the S/I for the current pulse is greater than SIRATM, SIRATM is updated with the S/I for the current pulse (Block 7). Execution then loops back to Block 1. The loop encompassing Blocks 1-7 is performed (for sector search) until either the simulation terminates, or until all pulses in a vertical scan are processed (a "yes" condition occurs at Block 5).

Block 8. The next execution path depends on the detection model chosen by the user. If the threshold detection model is used (DETTYP = THRS), execution branches to Block 9. If the Pd model is chosen (DETTYP = PDET), execution branches to Block 12.

Blocks 9-11. The threshold detection model implementation begins. Several conditions are checked to support a subsequent detection decision. If the ground clutter power (CL) is less than one-tenth of the power due to the target return (TS) (Block 9), then if the S/I (SIRAT or SIRATM) is greater than the user-defined threshold (THRESH(1)) for a "blue sky" condition (Block 10), a target detection has occurred; if the S/I is less than or equal to THRESH(1) at Block 10, a no-detection condition exists, and execution transfers from Block 10 to Block 1.

If the ground clutter is greater than or equal to one-tenth of the target return power (Block 9), a "clutter condition" exists, and the S/I is compared with the user-specified threshold (THRESH(2)) for a cluttered environment (Block 11). If the S/I is greater than THRESH(2), a detection has occurred; otherwise, another attempt at detecting the target with the next pulse (or vertical scan) is implemented through transfer of execution from Block 11 to Block 1 (indicated by A). Character variable RSTAT is set to "DETECTED" in Block 18 only if detection criteria are met.

Block 12. A different execution branch occurs after Block 8 if the user chose the Pd model (DETTYP = PDET). In this case, if S/I is greater than 1, the P_d is calculated in the following two blocks.

Block 13. The bias level (YB) is calculated in Subroutine PRBDET as described earlier in the Bias Level Algorithm portion.

Block 14. In Subroutine PRBDET, the P_d value is calculated and passed to the applicable subroutine (PERCUE, SRCH1) as variable PD. Section 2.4, Signature Fluctuations, discusses calculation of P_d.

Block 15. If the P_d is greater than the user-specified requirement for detection (THRESH(1)), execution continues to Block 16. Otherwise, another attempt at detecting the target with the next pulse (or vertical scan) occurs by transfer of execution to Block 1 (indicated by A).

Blocks 16-17. Perfect cuing search mode requires only one occurrence of a detected target signal to declare a detection condition in Block 18. If a sector or circular search mode is chosen by the user (variable SCHPAT = SECT or CIRC), the first occurrence of a target signal detection sends execution to Block 17, where a variable NDET1 is set to a value of one, and execution transfers back to the beginning of the functional flow for the FE. Variable NDET2 is set to NDET1; if a second consecutive signal detection results from the next comparison, the NDET2 =1 condition causes an execution transfer to Block 18.

Block 18. The character variable RSTAT is set to "DETECTED" to establish a target detection status in RADGUNS. The procedures of the Detection Threshold FE are complete at this point.

If the target is detected, the acquisition mode of the radar ends, and an attempt to establish target track is performed by Subroutine ENGAGE. The scope of this FE is limited to the acquisition mode.

The target may never be detected in some scenarios. In those cases, a simulation termination criteria eventually will be found in Block 2. In fact, a no-detect status of the target that persists long enough will generate a termination condition at Block 2.

Functional Element Inputs and Outputs

The outputs of this functional element are given in Table 2.22-2. User inputs which affect threshold are given in Table 2.22-3. Local variable inputs to this functional element are given in Table 2.22-4. Refer to Section 2.4 for inputs and outputs of modules PRBDET, DGAM, DEVAL, and SUMLOG; that section describes functions GAM and EVAL, which also describe functions DGAM and DEVAL, respectively. Table 2.22-2 shows the FE output.

TABLE 2.22-2. FE Outputs.

Variable Name	Description
YB	Bias level (Volts) calculated in Subroutine PRBDET
RSTAT	Status of detection of target (detected or not detected)

Table 2.22-3 displays the user-defined input data to the FE.

TABLE 2.22-3. User Inputs to FE.

Variable Name	Variable Options	Description
DETTYP	PDET, THRS	Type of target detection model PDET = P_d model THRS = threshold detection model

TABLE 2.22-3. User Inputs to FE.

SCHPAT	PERC, SECT, CIRC	Radar search pattern PERC = Perfect Cueing, SECT = Sector Search, CIRC = Circular Search
THRESH(2)	If PDET, not used If THRS, any real number	Power-to-interference detection threshold (dB) in a cluttered environment
THRESH(1)	If PDET, 0 If THRS, any real number	If PDET, "threshold" for P_d If THRS, power-to-interference detection threshold (dB) in a non-cluttered environment

Some inputs to modules implementing the FE are used to calculate variables specific (local) to a module that also are inputs to the FE. These local variables are described in Table 2.22-4.

TABLE 2.22-4. Local Variable Inputs to FE.

Variable Name	Module	Description
SIRAT	PERCUE, SRCH1	S/I, interference is the sum of ground clutter and receiver thermal noise
TS	PERCUE, SRCH1	Returned signal from target including multipath effects (W)
CL	PERCUE, SRCH1	Returned signal from ground clutter (W)
PD	PERCUE, SRCH1	Probability of detection

Subroutines PERCUE and SRCH1 simulate operation of the radar system in perfect cuing, sector search, and circular search modes. These routines also perform calculations used to determine the target detection status. The bias level is determined by Subroutines PRBDET, DGAM, DEVAL, and SUMLOG. The input and output data of these routines which support the Detection Threshold FE are identified in Tables 2.22-5 through 2.22-10. Variable names highlighted in bold denote those which directly implement the FE, or are outputs of the FE.

TABLE 2.22-5. Subroutine PERCUE Input and Output.

SUBROUTINE: PERCUE					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
AMAXEL	Common	Maximum antenna elevation angle (rad)	BSITE	Common	Target azimuth (rad), elevation (rad), range (m) (boresight data)
DETTYP	Common	Type of detection method (S/I or Pd data for threshold)	MTISW	Common	Moving Target Indicator "switch" (ON-OFF)

TABLE 2.22-5. Subroutine PERCUE Input and Output. (Contd.)

SUBROUTINE: PERCUE					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
ECHO	Common	Power of target return without multipath effects (W)	OPTOUT	Common	Array which stores “important” values of variables
ELMTI	Common	Maximum elevation angle for MTI to be utilized (rad)	RSTAT	Argument	Status flag for target detection
FMP	Common	Multipath factor	T	Argument	Time since simulation began (s)
GANTA	Common	Radar antenna gain at center of beam			
MOVMNT	Common	Course and speed of a moving weapon system (deg, knots)			
MTICHG	Common	Logical variable, true for a dynamic MTI setting			
NPSCAN	Common	Number of pulses per vertical scan			
RDRSYS	Common	AAA system simulated			
RGMAX	Common	Tactical range of guns (m)			
SIMTYP	Common	Type of simulation (single fly-by, multiple fly-by, detection only)			
STMIN	Common	Minimum search time (s)			
SUDAPP	Common	Logical variable, true if target suddenly appears at close range			

TABLE 2.22-5. Subroutine PERCUE Input and Output. (Contd.)

SUBROUTINE: PERCUE					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
T	Argument	Time since simulation began (s)			
TEKON	Common	Logical variable, true if Tektronix graphics file will be created			
THRESH	Common	S/I or P_d detection “threshold”			
TOTSHL	Common	Number of shells in magazine (unfired)			
TWOPI	Common	2 x			

TABLE 2.22-6. Subroutine SRCH1 Input and Output.

SUBROUTINE: SRCH1					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
AMAXEL	Common	Maximum antenna elevation angle (rad)	BSITE	Common	Target azimuth (rad), elevation (rad), range (m) (boresight data)
AMINEL	Common	Minimum antenna elevation angle (rad)	MASKED	Common	Logical variable, true if target is masked
DETTYP	Common	Type of detection method (S/I or Pd data for threshold)	MTISW	Common	Moving Target Indicator “switch” (on-off)
ECHO	Common	Power of target return without multipath effects (W)	OPTOUT	Common	Array which stores “important” values of variables
ELMTI	Common	Maximum elevation angle for MTI to be utilized (rad)	RSTAT	Argument	Status flag for target detection
FMP	Common	Multipath factor	T	Argument	Time since simulation began (s)
HILLON	Common	Logical variable, true when a user-defined hill is used			
MOVMNT	Common	Cause and speed of a moving weapon system (deg, knots)			

TABLE 2.22-6. Subroutine SRCH1 Input and Output. (Contd.)

SUBROUTINE: SRCH1					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
MTICHG	Common	Logical variable, true for a dynamic MTI setting			
PNOISA	Common	Receiver noise factor (W)			
PRI	Common	Pulse repetition interval (s)			
RDRSYS	Common	AAA system simulated			
SCHPAT	Common	Radar search mode			
SECWID	Common	Width of sector scan (deg)			
SIMTYP	Common	Type of simulation (single fly-by, multiple fly-by, detection only)			
SRCHAZ	Common	Initial search azimuth (deg)			
SRCHEL	Common	Search elevation angle (deg)			
T	Argument	Time since simulation began (s)			
THRESH	Common	S/I or Pd detection “threshold”			
TOTSHL	Common	Number of shells in magazine (unfired)			
TWOPI	Common	2 x			
VHORO	Common	Radar horizontal scan rate (deg/s)			

TABLE 2.22-7. Subroutine PRBDET Input and Output.

SUBROUTINE: PRBDET					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
KASE	Argument	Swerling fluctuation case	PD	Argument	Probability of detection
NPI	Argument	Number of pulses integrated			
PFA	Argument	Absolute value of the exponent of the power of ten expression for Pfa			
SNDB	Argument	S/I power ratio (dB)			

TABLE 2.22-8. Subroutine DGAM Input and Output.

SUBROUTINE: DGAM					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
B	Argument	Real number (bias level for Threshold FE)	DGAM	Function	Calculate approximation to the incomplete gamma function
N	Argument	Integer (number of pulses integrated for Threshold FE)			

TABLE 2.22-9. Subroutine DEVAL Input and Output.

SUBROUTINE: DEVAL					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
Y	Argument	Real number (bias level for Threshold FE)	DEVAL	Function	Calculate a term of approximation to the incomplete gamma function
N	Argument	Integer (NPI for Threshold FE)			
SUML	Argument	Value returned from Function SUMLOG			

TABLE 2.22-10. Subroutine SUMLOG Input and Output.

SUBROUTINE: SUMLOG					
Inputs			**Outputs**		
Name	**Type**	**Description**	**Name**	**Type**	**Description**
N	Argument	Integer (NPI for Threshold FE)	SUMLOG	Function	Accumulate natural logarithms of integers up to value of N

2.22.4 Assumptions and Limitations

No assumptions or limitations apply to the Detection Threshold FE.